Global Risks in the Currency Market

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ABFER

May 24, 2018

Motivation I

- In the currency market risk factors are typically seen as global, i.e. affecting all economies/currencies
  - global equity volatility risk: Lustig, Roussanov and Verdelhan (RFS, 2011)
  - global currency volatility risk: Menkhoff et al. (JF,2012)
  - global imbalance risk: Della Corte, Riddiough and Sarno (RFS,2016)
  - global growth news risk: Colacito, Croce, Gavazzoni and Ready (JF,2018)
  - global macro risk: Berg and Mark (2017)
- "Global risks require compensation from the perspective of all investors, regardless of their home currency."

Motivation II

- The test assets in standard pricing tests must be denominated in some individual currency.
- And this choice could matter: e.g., the usual interest-rate sorted portfolios, when denominated in USD, GBP and JPY have average correlation of about 30%.
- What can we then say about the global nature of a factor if it performs differently for returns in different denominations? How do we compare statistically the results obtained in different denominations?
- Taking the perspective of the US investor?

Motivation III

- How has the issue been addressed?
  - Verdelhan (2017) calculates returns from several currency perspectives (his Table 6). How to show statistically equivalence of the results?
  - Hassan-Mano (2017) provide a statistical test (their Section 3.3), but only in one special case
  - Aloosh and Bekaert (2017) also consider returns with many base currencies, and suggest factors which aggregate several currency perspectives
- This paper:
  - constructs a novel cross section of currency trades, with largely the same returns from the perspective of any currency: numeraire-invariant.
  - while such test assets can be constructed in many ways, we focus on a cross section of carry trades

This paper's approach

- First present some new empirical findings related to a widely considered global risk factor - the US dollar - using the invariant cross section.
- Examine these findings within the modeling framework of Lustig, Roussanov and Verdelhan (2014) (in reduced form, with two global risk factors).
- Suggest a modification that can reconcile the model with the data, while preserving the original model calibration. I.e., make the sensitivity to one of the global factors in the model time-varying and dependent on the relative US risk-free rate.
- Evaluate a large number of global risk factors considered in prior studies. The factors should:
  - explain the invariant cross section in standard asset pricing tests
  - agree with the modified LRV model. The role of the model is to impose discipline in the search for global risk factors and their economic interpretation.

Main results

- The average returns of the invariant carry trades are highly correlated with the betas of these trades with respect to a dollar factor, so dollar risk is priced in this cross section. However: this feature stems only from the subsample where the US interest rate is relatively low.

- The modified LRV model where the dispersion in the sensitivities of different economies to one of its global risk factors depends on the US interest rate can generate this feature.

- Only few combinations of previously suggested variables come close to meeting the model's requirements, and even they fall short in some dimensions.

- The global equity market factor stands out as the the only one which can qualify for the factor with time-varying sensitivity. The risks in the currency market can also be linked with the Global financial cycle in Rey (2015).

- Global risks still pose a challenge for the empirical research of the currency market.

Contribution of the paper

- Builds on Lustig et al. (2011, 2014):
  - similar to Brusa et al. (2015), Mueller et al. (2017), Verdelhan (2017)
  - asserts further the link between asymmetric exposure to global risk and carry trade profitability
  - pricing ability of a dollar factor (DOL); the average forward differential (AFD) of the USD is a key conditioning variable
- But also departs from these prior studies:
  - numeraire-invariant long-short trades instead of long-only currency portfolios
  - DOL can price carries, so no strict separation between dollar and carry risks
  - DOL's pricing ability is built mechanically into the modified LRV model, so may not represent a separate source of global risk.
  - AFD affects all economies, not just an indicator of US specifics
  - persistent (and possibly counter-cyclical) differences in the exposures to standard systematic risks (global equity market risk); similar exposure to volatility risk and other uncertainty-related variables.

The invariant cross section

- Assume the USD is the numeraire currency, and a trade where currency i has weight w_t^i at time t. For spot and forward exchange rates denoted as S_t^i and F_t^i (USD per one unit of foreign currency) the return of the USD-based trade is:

$$r_{t+1}^{USD} = \sum_{i=1}^{N} w_t^i \left(S_{t+1}^i / F_t^i - 1 \right)$$

- If the JPY exchange rates are $\overline{S}_t^i$ and $\overline{F}_t^i$ (JPY per one unit of currency i), the return (in JPY) is:

$$r_{t+1}^{JPY} = \sum_{i=1}^{N} w_i \left(\overline{S}_{t+1}^i / \overline{F}_t^i - 1 \right) = \sum_{i=1}^{N} w_t^i \, \overline{S}_{t+1}^i / \overline{F}_t^i - \sum_{i=1}^{N} w_t^i$$

- If the short and long legs of the trade have equal weight, the same for all currency perspectives, then $\sum_{i=1}^{N} w_t^i = 0$. By triangular arbitrage:

$$r_{t+1}^{JPY} = \sum_{i=1}^{N} w_t^i \overline{S}_{t+1}^i / \overline{F}_t^i = \left(r_{t+1}^{USD} + \sum_{i=1}^{N} w_i \right) \overline{S}_{t+1}^{USD} / \overline{F}_t^{USD} = r_{t+1}^{USD} \underbrace{F_t^{JPY} / S_{t+1}^{JPY}}_{\text{close to 1}}$$

The invariant cross section

- The equality is exact in log returns:

$$
\begin{aligned}
r_{t+1}^{JPY} &= \sum_{i=1}^{N} w_t^i \log\left(\overline{S}_{t+1}^i / \overline{F}_t^i\right) = \sum_{i=1}^{N} w_t^i \log\left(S_{t+1}^i / F_t^i \;\; \overline{S}_{t+1}^{USD} / \overline{F}_t^{USD}\right) \\
&= \sum_{i=1}^{N} w_t^i \log\left(S_{t+1}^i / F_t^i\right) + \sum_{i=1}^{N} w_t^i \log\left(\overline{S}_{t+1}^{USD} / \overline{F}_t^{USD}\right) \\
&= \sum_{i=1}^{N} w_t^i \log\left(S_{t+1}^i / F_t^i\right) + \log\left(\overline{S}_{t+1}^{USD} / \overline{F}_t^{USD}\right) \sum_{i=1}^{N} w_t^i = \sum_{i=1}^{N} w_t^i \log\left(S_{t+1}^i / F_t^i\right) = r_{t+1}^{USD},
\end{aligned}
$$

- Consider all carry trades that use all possible combination of eight out of the ten G-10 currencies (total of 45), over 12/1984-11/2016

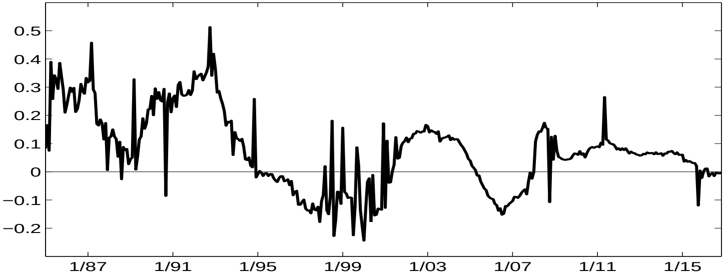
	avg.ret.	st.dev.	SR	skew
SC	2.38	4.58	0.52	-0.84
max	2.86	4.67	0.71	-0.01
median	2.28	4.13	0.53	-0.61
min	1.21	3.41	0.30	-0.82
prop. below	0.62	0.84	0.49	0.00

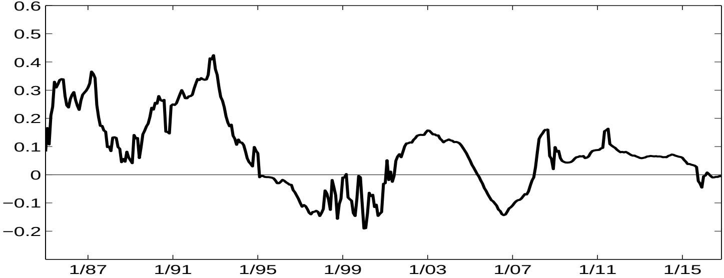
Average returns and dollar betas

- Is US dollar risk priced in the invariant carry cross section? As in LRV (2014), we also consider subperiods when the average forward differential (AFD) of the USD is positive or negative.
- Use the dollar factor DOL - the return of an equally weighted portfolio of long positions in all G-10 currencies against the USD
- Univariate regressions (with a constant) of carry trade returns on DOL. Betas and correlations between betas and the average returns carry returns.

	full				$AFD < 0$				$AFD > 0$			
No.	corr.	β_{5-th}	β_{95-th}	sign.	corr.	β_{5-th}	β_{95-th}	sign.	corr.	β_{5-th}	β_{95-th}	sign.
45	0.75	0.07	0.24	(45)	0.05	-0.28	-0.11	(38)	0.73	0.15	0.33	(45)
10	0.80	0.10	0.22	(10)	0.12	-0.27	-0.13	(10)	0.75	0.17	0.33	(10)
120	0.66	0.03	0.25	(105)	-0.07	-0.30	-0.06	(90)	0.69	0.10	0.35	(120)

The average forward differential (AFD)





Why the LRV model?

- Offers a parametric currency cross section and allows to simulate realistic carry trade returns and formalize the relation between their average returns and dollar betas.
- Time-varying relation between DOL and carry risks in the data: different factors determine carry returns over the two AFD subsamples. The LRV model features two global risk factors.
- In the model, carry trade profitability is theoretically linked to asymmetric exposure to (one) global risk, which we exploit.
- The model is in reduced form - offers flexibility in the search for factors.

The LRV model

- Log pricing kernel m^i of country i:

$$
\begin{aligned}
-m^i_{t+1} &= \alpha + \chi z^i_t + \sqrt{\gamma z^i_t}u^i_{t+1} + \tau z^w_t + \sqrt{\delta^i z^w_t}u^w_{t+1} + \sqrt{\kappa z^i_t}u^g_{t+1}, \\
z^i_{t+1} &= (1-\phi)\theta + \phi z^i_t - \sigma\sqrt{z^i_t}u^i_{t+1}, \qquad z^w_{t+1} = (1-\phi^w)\theta^w + \phi^w z^w_t - \sigma^w\sqrt{z^w_t}u^w_{t+1}
\end{aligned}
$$

- Interest rates r^i_t, DOL and the return of an invariant carry trade are:

$$
\begin{aligned}
r^i_t &= \alpha + \left(\chi - \frac{1}{2}(\gamma+\kappa)\right) z^i_t + \left(\tau - \frac{1}{2}\delta^i\right) z^w_t \\
DOL_{t+1} &= \frac{1}{2}(\gamma+\kappa)(z_t - \overline{z^i_t}) + \frac{1}{2}(\delta - \overline{\delta^i})z^w_t \\
&\quad + \sqrt{\gamma z_t}u_{t+1} - \overline{\sqrt{\gamma z^i_t}u^i_{t+1}} + \left(\sqrt{\delta} - \overline{\sqrt{\delta^i}}\right)\sqrt{z^w_t}u^w_{t+1} + \sqrt{\kappa}\left(\sqrt{z_t} - \overline{\sqrt{z^i_t}}\right)u^g_{t+1} \\
rx^{carry}_{t+1} &= -\frac{1}{2}(\gamma+\kappa)\widetilde{z^i_t} - \frac{1}{2}\widetilde{\delta}^i z^w_t - \widetilde{\sqrt{\gamma z^i_t}u^i_{t+1}} - \widetilde{\sqrt{\delta^i}}\sqrt{z^w_t}u^w_{t+1} - \sqrt{\kappa}\widetilde{\sqrt{z^i_t}}u^g_{t+1}
\end{aligned}
$$

Simulated correlations b/n DOL and carries in the LRV model

- Simulate 1000 sets of 11 interest rate and 11 exchange rate series
- From each set construct a cross section of 55 carry trades, all possible combinations of nine out of the 11 simulated currencies, long (short) the three currencies with highest (lowest) interest rate.

full				$AFD < 0$				$AFD > 0$			
corr	β_{5-th}	β_{95-th}	sign.	corr	β_{5-th}	β_{95-th}	sign.	corr	β_{5-th}	β_{95-th}	sign.
0.091	-0.02	0.05	(24.5)	0.042	-0.27	-0.14	(53.1)	0.073	0.14	0.28	(53.7)

- One percent of the simulated correlations in the full sample are above 0.72, (0.75 in the data)
- One percent of the simulated correlations when $AFD > 0$ are above 0.69 (0.73 in the data)

Modifying the LRV model

- A modified model should give:
  - high positive correlation between average carry returns and DOL betas (full sample and when $AFD > 0$)
  - positive DOL betas (full sample and when $AFD > 0$)
  - correlation ≈ 0 and negative DOL betas when $AFD < 0$
  - (desirable) high Sharpe ratio of the Dollar carry trade - an issue for the original LRV model

- We suggest a time-varying dispersion in the parameters δ^i (deltas) in the LRV model (sensitivities to the global factor u^w)

- High dispersion when $AFD > 0$, and low otherwise. The "LRV^d model".

The LRV^d model

$$
\begin{aligned}
DOL_{t+1} &= \frac{\kappa}{2}(z_t - \overline{z_t^i}) + \left(\sqrt{\delta} - \overline{\sqrt{\delta_t^i}}\right)\sqrt{z_t^w}u_{t+1}^w + \sqrt{\kappa}\left(\sqrt{z_t} - \overline{\sqrt{z_t^i}}\right)u_{t+1}^g \\
rx_{t+1}^{carry} &= -\frac{\widetilde{\delta_t^i}}{2}z_t^w - \frac{\kappa}{2}\widetilde{z_t^i} - \widetilde{\sqrt{\delta_t^i}}\sqrt{z_t^w}u_{t+1}^w - \sqrt{\kappa}\widetilde{\sqrt{z_t^i}}u_{t+1}^g \\
COV^{rx^{carry},DOL} &= -\frac{\kappa^2}{4}E[(z_t - \overline{z_t^i})\widetilde{z_t^i}] - E\left[\left(\sqrt{\delta} - \overline{\sqrt{\delta_t^i}}\right)\widetilde{\sqrt{\delta_t^i}}z_t^w\right] - \kappa E\left[\left(\sqrt{z_t} - \overline{\sqrt{z_t^i}}\right)\widetilde{\sqrt{z_t^i}}\right] \\
&\approx \underbrace{-\frac{\kappa^2 N}{4(N-1)}E[z_t\widetilde{z_t^i}]}_{A} \underbrace{- E\left[\left(\sqrt{\delta} - \overline{\sqrt{\delta_t^i}}\right)\widetilde{\sqrt{\delta_t^i}}\right]\theta^w}_{B} \underbrace{- \frac{\kappa N}{N-1}E\left[\sqrt{z_t}\widetilde{\sqrt{z_t^i}}\right]}_{C}
\end{aligned}
$$

- When $AFD > 0$, the high-dispersion deltas dominate the interest rates, $\widetilde{\sqrt{\delta_t^i}}$ is negative and large, B generates positive DOL beta. Then the $-\frac{\widetilde{\delta_t^i}}{2}z_t^w$ in rx_{t+1}^{carry} brings high correlation with average returns, as in the data.
- When $AFD < 0$, deltas are compressed, interest rate differentials are dominated by z_t and the z^i's, USD more likely to enter the trades (long), z_t will have positive weight in $\widetilde{z_t^i}$, and A and C generate negative DOL beta, as in the data.

Simulating the LRV and LRV^d models

	$\delta^i_t = \delta + \nu_t(\delta^i - \delta)$		$\kappa_t = \xi_t \kappa$		
	ν_t		ξ_t		γ
	$AFD < 0$	$AFD > 0$	$AFD < 0$	$AFD > 0$	
LRV	1	1	1	1	0.04
V_1	0	2.5	1	1	0.00
V_2	0.5	2.5	0.95	1.05	0.00
V_3	1	2.5	0.95	1.05	0.01

							Sharpe ratio	
	$\overline{r}$	$\overline{\sigma_r}$	$\overline{rx}$	$\overline{\sigma_{rx}}$	$\overline{\rho_r}$	$\overline{\rho_{rx}}$	DC	SC
LRV	4.24	0.29	0.63	10.4	0.11	0.41	0.24	0.48
V_1	4.44	0.44	0.54	9.0	-0.001	0.23	0.43	0.36
V_2	4.46	0.43	0.64	9.1	0.11	0.22	0.43	0.37
V_3	4.41	0.39	0.71	10.1	0.17	0.25	0.37	0.36

	full			$AFD < 0$			$AFD > 0$		
	corr	β_{5-th}	β_{95-th}	corr	β_{5-th}	β_{95-th}	corr	β_{5-th}	β_{95-th}
data	0.75	0.07	0.24	0.05	-0.28	-0.11	0.73	0.15	0.33
LRV	0.09	-0.02	0.05	0.04	-0.27	-0.14	0.07	0.14	0.28
V_1	0.64	0.09	0.25	-0.02	-0.75	-0.64	0.65	0.75	1.03
V_2	0.59	0.17	0.36	-0.01	-0.61	-0.44	0.64	0.75	1.01
V_3	0.57	0.18	0.34	0.16	-0.30	-0.12	0.55	0.54	0.74

Further promise of the LRV^d model

- Agrees with the evidence on the static and dynamic components of the carry trade, as in Hassan and Mano (2017)
- Relates to other evidence on counter-cyclical cross-sectional dispersions:
  - industry betas - Baele and Londono (JEF,2013), Gomes, Kogan, and Zhang (JPE,2003)
  - market betas - Frazzini and Pedersen (JFE,2013)
  - for various firm-level variables - Bloom (Ecma,2009)
  - banks' equity returns Christiano and Ikeda (AER,2013)

Design of asset pricing tests

- Cross-sectional asset pricing tests - standard GMM framework

- Added: mis-specification robust standard errors as in Kan, Robotti and Shanken (JF,2013), and tests comparing nested models

- Among a number of candidate global risk factors, look for pairs f_t^1 and f_t^2 which can reflect time-varying delta dispersion

- Estimate linear three-factor models:

$$rx_{t+1}^{carry,i} = \alpha^i + \xi_1^i f_{t+1}^1 + \beta_2^i f_{t+1}^2 + \xi_2^i f_{t+1}^1 \mathbb{1}_{AFD_t>0} + \epsilon_{t+1}^i.$$

- The slope on f^1 is $\beta_1^i = \xi_1^i$ when $AFD_t < 0$ and $\beta_1^i = \xi_1^i + \xi_2^i$.

- Two key requirements from the LRV^d model:
  - ξ_2 should be statistically significant
  - since $\beta_1^i \approx -\widetilde{\sqrt{\delta^i}}\sqrt{\nu_t \theta^w}$, it should be larger in magnitude when $AFD > 0$.

Candidate global risk factors

	abbrev.	availability	data source
MSCI-World	MSCI	12/1984 to 11/2016	Datastream
Barclay's Glob. Aggr. Bond indx	BGAB	12/1989 to 11/2016	Bloomberg
Barclay's Glob. Treas. Bond indx	BGT	12/1986 to 11/2016	— " —
Barclay's Glob. HYld Bond indx	BGHY	12/1989 to 11/2016	— " —
CRB commodity price index	CRB	12/1984 to 11/2016	Datastream
Baltic Dry index	BDI	05/1985 to 11/2016	— " —
Global equity volatility	GEV	12/1984 to 06/2015	Lustig et al. (2011)
Global currency volatility	FXV	12/1984 to 11/2016	Menkhoff et al. (2012)
VIX	VIX	01/1986 to 11/2016	www.cboe.com
Conditional variance	CV	01/1990 to 11/2016	Bekaert & Hoerova (2014)
Variance premium	VP	01/1990 to 11/2016	— " —
Variance risk premium	VRP	01/1990 to 11/2016	Bollerslev et al. (2009)
Financial uncertainty	FINU	12/1984 to 11/2016	Jurado et al. (2015)
Macroeconomic uncertainty	MCRU	— " —	— " —
Global uncertainty index	GU	11/1989 to 07/2014	Ozturk and Sheng (2016)
Global political risk indx	GPR	01/1985 to 11/2016	Caldara & Iacoviello (2016)
Baker-Bloom-Davis MPU indx	MPU1	— " —	www.policyuncertainty.com
Husted-Rogers-Sun MPU indx	MPU2	— " —	— " —

- Consider all 306 ordered pairs.
- Accept a pair if at least half of the ξ_2's are significant and $|\xi_1 + \xi_2| > |\xi_1|$ for at least half of the 45 carry trades.

Test results I

- The results are quite unexpected!
- Only 12 (out of 306!) pairs meet the requirements.
- Only one variable qualifies for the role of the f^1 factor: the global equity market index (MSCI-World).
- No pair performs well in all statistical dimensions.

Test results II

$$rx_{t+1}^{carry,i} = \alpha^i + \xi_1^i f_{t+1}^1 + \beta_2^i f_{t+1}^2 + \xi_2^i f_{t+1}^1 \mathbb{1}_{AFD_t>0} + \epsilon_{t+1}^i$$

nested models

f^1	f^2	α	sig.	ξ_1	sig.	β_2	sig.	ξ_2	sig.	R^2	p_1	p_2	p_3	p_4
MSCI	BGHY	1.32	(16)	-0.02	(1)	0.09	(37)	0.09	(38)	17.3	0.19	0.26	0.33	0.34
MSCI	BDI	1.68	(30)	0.02	(4)	0.02	(0)	0.08	(25)	10.0	0.10	0.18	0.12	0.11
MSCI	VIX	2.00	(43)	-0.01	(1)	-0.21	(44)	0.08	(28)	13.8	0.11	0.18	0.22	0.21
MSCI	MPU1	2.07	(42)	0.01	(3)	-0.02	(32)	0.08	(28)	11.1	0.06	0.12	0.11	0.09
MSCI	MCRU	1.69	(33)	0.02	(4)	-0.05	(5)	0.08	(25)	10.5	0.09	0.18	0.16	0.14
DOL	SC	0.12	(3)	-0.03	(21)	0.80	(45)	0.08	(33)	83.9	0.28	0.29	0.13	0.12

$$E[rx_{t+1}^i] = \lambda' \beta^i$$

		λ_1	p-val	p-rob	λ_2	p-val	p-rob	λ_3	p-val	p-rob	R^2_{CS}	GRS	χ^2	CSRT
MSCI	BGHY	33.5	0.01	0.00	1.9	0.75	0.77	26.1	0.01	0.00	66.9	0.23	0.45	0.88
MSCI	BDI	27.6	0.01	0.02	-12.6	0.10	0.11	24.7	0.01	0.01	70.1		0.73	0.90
MSCI	VIX	35.7	0.00	0.01	-2.5	0.41	0.39	28.9	0.00	0.00	58.3		0.80	0.95
MSCI	MPU1	32.2	0.01	0.02	20.5	0.58	0.54	26.9	0.00	0.00	44.6		0.19	0.82
MSCI	MCRU	32.3	0.02	0.12	8.3	0.40	0.64	26.1	0.01	0.02	42.8		0.37	0.73
DOL	SC	6.2	0.02	0.03	2.4	0.00	0.01	5.8	0.00	0.00	51.3	0.00	1.00	0.89

Robustness checks

- construction of the test assets - different currency perspectives (related to Maurer, To and Tran (2018))
- the AFD - smoothed or raw
- orthogonalizing the factors as in the LRV model

The two AFD regimes

- $AFD > 0$
  - lower output growth and growing unemployment
  - decreasing uncertainty
  - stagnant or slowly growing (relative to global GDP) cross-border bank loans in foreign currency
  - lower US interest rates (by design), and depreciating USD
  - covers about 70% of the sample period. "normal" regime?

- $AFD < 0$
  - stronger real global economy
  - increasing uncertainty
  - increasing liquidity
  - higher US interest rates and appreciating USD
  - about 70% of the sample period. "boom" regime?

AFD regimes and the Global financial cycle

Counter-cyclical dispersion in FX - is it a puzzle?

- Bloom (2014): "counter-cyclical dispersion in various economic variables reflects the behavior of uncertainty over time. Uncertainty endogenously increases during recessions, as lower economic growth induces greater micro- and macro-uncertainty." However, in the AFD regimes higher uncertainty goes together with higher economic growth. A different cycle?

- Frazzini and Pedersen (2013): the cross-sectional dispersion in (market) betas lower when credit constraints binding and credit more likely to be rationed. However, we see strong global liquidity growth in the AFD regime of low cross-sectional dispersion. Consistent?

- Bruno and Shin (2015): a contractionary shock to US monetary policy leads to a decrease in cross-border banking capital flows and a decline in the leverage of international banks and appreciation of the US dollar. However, we see dollar appreciation together with increased bank flows when $AFD < 0$.

Conclusion

- A growing list of variables have been suggested as global currency risk factors
- This paper adds two main components:
  - numeraire invariant cross section of currency trades
  - tests consistent with implications of the LRV model with two global factors
  - to agree with new dollar-related stylized facts, time-varying dispersion included in the model
- Evaluate a range of factors from prior carry studies
- Only a few combinations of factors can meet our requirements. Special role of a global equity market factor and the Global financial cycle
- Evidence for counter-cyclical dispersion in risk sensitivities
- Economic interpretations still to be developed